Content of Mineral N in Soil and Tomato Yields Considering Fertigation and Mulch

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Summary

The objective of this study was to determine the effect of application of different amounts of N fertilizer added by fertigation and different mulches on the total mineral N in the plough soil layer and yield of tomatoes. The two-year study (2007 and 2009) was conducted on hydromeliorated deep Terra Rossa near Pula. In two-factor experiment, set in a split-plot design, the main factor was N fertilization (NF) in three levels: 60 (NF1), 120 (NF2), and 180 (NF3) kg N ha^{-1}. Subfactor was soil mulch (M), also in three levels: without mulch (WM), straw mulch (SM), and mulch with black polyethylene film (BPM). Different NF significantly affected the amount of N min in the soil. Only in 2009, mulch as well as interaction between NF and DAT had significant impact on the amount of N min in soil. Nitrogen fertilization did not significantly affect the total yields of tomatoes, except the application of NF2 and BPM that generated significantly higher yields of tomatoes in 2007. Recommended technology is application of NF2 and BPM, but with ecological point of view it would be justified to use the nitrogen fertilization with only 60 kg N ha^{-1}.

Key words

fertigation, mulch, soil, mineral nitrogen, tomato

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Introduction

The production of tomatoes in the Republic of Croatia is significantly lower compared to global framework, since Croatia is ranked 99th in the total world production (EUROSTAT, 2012). Intensive production of tomatoes is achieved by regular irrigation and the use of larger amounts of mineral and organic fertilizers, as well as a variety of materials for mulching soil (Elia and Conversa, 2012). Uncontrolled use of N fertilizers is a potential threat for leaching and groundwater pollution. This is particularly evident in the karst area, which is due to its geological and pedological specifications very vulnerable to anthropogenic impacts (Albertin et al., 2011). The fertigation is usually applied in tomato production, which increases the utilization of nutrients and water and reduces the economic losses (Cetin and Uygan, 2008). Using the polymer / PE mulch, and black, transparent and semitransparent foils and films directly affects an increase of soil temperature (Ban et al., 2009), the faster growth of plants, earlier ripening and yield increase (Rashidi et al., 2009). The main objectives of research were: (1) monitoring the dynamics of the total N min in the plough soil layer (0-30 cm), and (2) analysis of the amount of the total yield of tomatoes, all in relation to the various treatments of NF, M and NF x M.

Materials and methods

The experiment with tomato (*Lycopersicum esculentum* L.), F1 cultivar Elco (Clause Tezier – Harris Moran, France) was carried out in 2007 and 2009 in the trial field of Valtura, situated 5 km northeast from Pula (44° 51′ N, 13°51′ E, 10 m a.s.l.). Climate data for both years, as well as the long-term average (1980-2009) were measured at the meteorological station Pula, as shown in Tables 1 and 2. The soil type was deep anthropogenic Terra Rossa. The surface soil layer was silty-loam texture, porous (45.5% vol), a medium soil capacity for water (39.0% vol) and low air capacity (6.5% vol). Dry bulk density was 1.39 g cm^{-3} and particle density was 2.56 g cm^{-3}. The total soil capacity for water was 118.4 mm, with 73.8 mm the plant available water and wilting point at 44.6 mm. The soil was acidic (pH in 1 MKCl = 5.30), with poor humus content (2.6%), moderately supplied with N (0.14%), and poorly supplied with plant available phosphorus (4.4 mg P_2O_5 100 g^{-1} of soil) and potassium (11.0 mg K_2O 100 g^{-1} of soil). Two-factor experiment was set in a split-plot design with three replications. The main factor NF had 3 levels: 60 (NF1), 120 (NF2), and 180 (NF3) kg N ha^{-1}. The subfactor M had also three levels: soil without mulch (WM), soil mulched with straw (SM), and mulched with black polyethylene film (BPM). Standard agrotechnical measures were applied: basic soil tillage to 30 cm depth, with the plowing of 40 t ha^{-1} of stable manure; basic fertilization with 600 kg N ha^{-1}; drip irrigation system, and soil mulching with SM and BPM. Planting of two months old seedlings was carried out in May 2007 and 2009. Basic fertilization with 42 kg N ha^{-1} was applied for all treatments, and the rest doses of 18, 78 and 138 kg N ha^{-1} were added during the vegetation by multiple fertigation. Side dressing was adjusted to soil moisture and growing stages of tomatoes. Nitrogen fertilizer UREA was added by fertigation (Table 3). In the vegetation of tomatoes amount of water added by drip irrigation was 350 mm (2009) and 389 mm (2007) in the average shifts of 6-7 days. Soil properties were analyzed by methods according to ISO standards: particle size distribution (ISO, 11377:2004), particle density (ISO 11508:2004), bulk density (ISO, 11272:2004), soil capacity for water (ISO, 11461:2001), soil water-retention characteristics (ISO 11274:2004), soil reaction (ISO, 10390: 2005), total N content (ISO 11261:2004), plant available P_2O_5 and K_2O (Egner et al., 1960), and humus content (Tjurin, 1937). Total N min in arable soil layer is defined as the sum of NO_3—N and NH_4^+-N according to Jackson (1958) and APHA (1992). Growth stages of tomatoes in both years were connected with days after transplanting the plant to field: beginning of vegetation (0 DAT), blooming (31 and 28 DAT), yield formation (45 and 58 DAT), the first harvest of tomatoes (74 and 87 DAT) and the end of the vegetation (104 and 115 DAT). During the study a total of 10 composite samples of soil were collected, which were obtained by mixing six individual samples from the middle row of each of the 27 treatments, Yield analysis of tomato harvest was conducted manually and repeatedly according to dynamics of fruit ripening. The obtained data regarding N min in the soil, as well as the yield of tomatoes in both years were statistically analyzed by ANOVA. Mean values of the mentioned parameters regarding various NF and M treatments, as well as DAT were compared by Duncan′s test at significance level of $p < 0.05$. The data were analyzed by computer program SAS and GLM procedure (SAS Institute Inc. 9.3.).

Table 1. Monthly rainfall during vegetation of tomato (2007 and 2009) and long term average rainfall (1980-2009)

Month	Rainfall, mm		Average rainfall, mm 1980-2009
	2007	2009	
V	114.9	4.8	62.1
VI	63.8	39.2	61.0
VII	7.5	33.0	40.5
VIII	76.6	68.3	63.8
IX	137.6	80.2	95.1
Total	400.4	225.5	322.5

Table 2. Average monthly air temperatures during vegetation of tomato and long term average air temperatures (1980-2009)

Month	Air temperature, °C		Average air temperature, °C 1980-2009
	2007	2009	
V	18.6	19.1	16.8
VI	22.3	20.8	20.6
VII	24.6	24.3	23.4
VIII	22.8	24.6	23.0
IX	17.3	20.9	18.6

Table 3. Monthly amount of N added by side dressing during the vegetation of tomato

NF *	N (kg Nha^{-1})								Total
	2007				2009				
	V	VI	VII	VIII	V	VI	VII	VIII	
NF1	1.4	4.3	9.5	2.7	2.3	6.8	7.7	1.1	18.0
NF2	6.2	18.7	41.3	11.7	10.1	29.6	33.5	4.7	78.0
NF3	11.0	33.1	73.1	20.7	17.9	52.4	59.3	8.3	138.0

* NF1 - 60 kg N ha^{-1}; NF2 - 120 kg N ha^{-1}; NF3 - 180 kg N ha^{-1}

Results and discussion

Results show that the amount of N min in the plough soil layer in 2007 was significantly affected by these factors: NF, DAT, and DAT x NF (Table 4). The total amount of N min in the soil during vegetation in 2009 was significantly affected by DAT, NF, M, DAT x NF, and DAT x M (Table 5). During the vegetation in 2007 amount of N min in the soil varied from 43.4 kg N ha^{-1} on the NF1 at 45 DAT to 105.3 kg N ha^{-1} on NF3 at 74 DAT (Fig. 1). The amounts of N min in the soil in 2009 were generally higher than in 2007 and ranged from 59.9 kg N ha^{-1} on the NF1 at 87 DAT to 189.6 kg N ha^{-1} on the NF3 at 28 DAT (Fig. 2). The amount of N min in the soil during 2007 was generally lower compared to 2009 what could be a result of different climatic conditions. Increased rainfall in 2007 and lower air temperature during the vegetation caused the faster leaching of N from soil, as well as its poor utilization by the plants. The dynamic of N min in soil show a certain regularity; amount of N min in soil decreases from the 0 DAT to the 45 and 58 DAT, when the most of N from the soil was spent for the development of generative organs of tomatoes. At 0 DAT were determined the lowest differences between the treatments of NF as the result of the application of the same mineral and organic fertilization. Higher amount of N in the soil at the beginning of the vegetation of tomatoes in 2009 was the result of residual N remained in soil after harvest of watermelon, as previous crop. In the growing stages 31-45 DAT in 2007 and 28-58 DAT in 2009 was the lowest amount of N min in the soil as result of intensive uptake of N by tomatoes. According to Hartz and Hanson (2009), N uptake by tomatoes in that period is consistent and moves up to 5.6 kg N ha^{-1} day^{-1}. It means that in our conditions would be enough N min in the soil for 10 days in 2007 or for 20 days in 2009 without side dressing of tomatoes with N. The secondary maximum was at 74 and 87 DAT, when maximal differences in the amount of N min in the soil between the treatments of NF were determined. This was the result of intensive uptake of N by tomatoes, but also the biggest difference in the amount of N added with side dressing. The phenophase leads to the withering of the flower floors of tomato leaves that reduces the assimilation of leaf surface, and thus the utilization of N from soil. Between 74-104 and 87-115 DAT the amount of N min in the soil was reduced as a result of maturity and disappearance of N by yield. The amount of N min in the soil at the end of vegetation of tomatoes was similar in our research with 73 – 89 kg N ha^{-1} received after fertigation of tomatoes with 200 kg N ha^{-1} (Tea et al., 1997) and derivate significantly from the 166 kg N ha^{-1} in the soil after fertilization of tomatoes with 208 kg Nha^{-1} in Catalonia (Doltra et al., 2010). Considering NF, throughout most of the vegetation the lowest amount of N min in the soil was determined in N1 and the highest in N3 treatments. Generally, the use of various mulch treatments had no impact on the amount of N min in the soil in 2007, while in 2009 the impact of mulch was significant (Tables 4 and 5). The quantities of N min in plough soil layers in 2009 were generally higher compared to 2007 and ranged from 479.33 kg N ha^{-1} in MW to 194.4 kg N ha^{-1} at BPM (2009), or from 48.44 kg N in WM to 156.5 kg N ha^{-1} at SM (2007). This is a result of higher rainfall during the vegetation in 2007, and the higher average air temperature in June and July. Although significant differences between BMP and the other two mulch treatments were attained at 0 DAT in 2009, in other part of vegetation they were not determined.

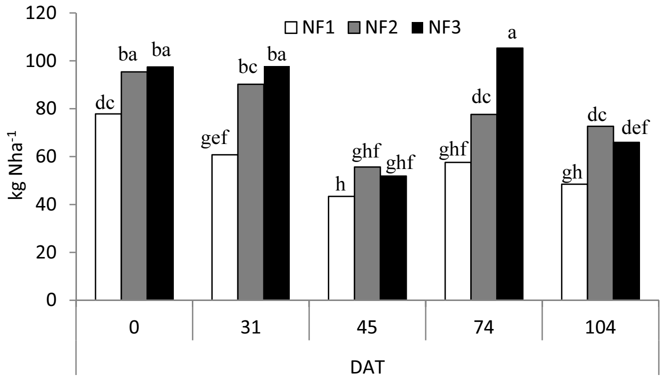
Table 4. ANOVA for N min in the soil in 2007

Source*	DF	Mean Square	F Value	Pr>F
DAT	4	7254.84	29.78	<0.001
NF	2	8543.61	35.07	<0.001
M	2	24.26	0.10	0.905
DAT x NF	8	725.42	2.98	0.005
DAT x M	8	212.78	0.87	0.542
DAT x NF x M	16	159.39	0.65	0.830
NF x M	4	80.45	0.33	0.857

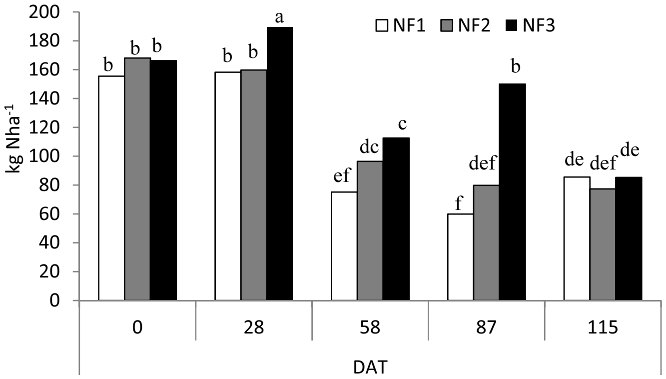
*DAT - date after transplatation; NF - nitrogen fertilization; M - mulch

Table 5. ANOVA for N min in the soil in 2009

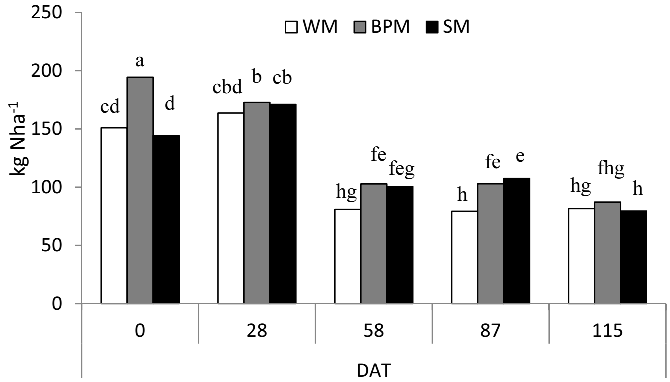
Source	DF	Mean Square	F Value	Pr>F
DAT	4	46271.10	98.65	<0.001
NF	2	13727.27	29.27	<0.001
M	2	4849.08	10.34	<0.001
DAT x NF	8	3251.87	6.93	<0.001
DAT x M	8	1382.83	2.95	0.006
DAT x NF x M	16	202.07	0.43	0.970
NF x M	4	383.4	0.82	0.517



Graph 1. N min content in plough soil layer related to DAT and NF, 2007



Graph 2. N min content in plough soil layer related to DAT and NF, 2009



Graph 3. N min content in plough soil layer related to DAT and M, 2009

Table 6. Total yield of tomato (t ha^{-1})

Treatments	2007	2009
	Nitrogen fertilization	
NF1	85.73 NS	118.56 NS
NF2	92.26 NS	127.70 NS
NF3	88.79 NS	126.70 NS
	Mulch	
WM	84.77 b	124.76 NS
BPM	102.65 a[1]	129.59 NS
SM	79.37 b	118.62 NS
	Nitrogen fertilization x Mulch	
NF1 x WM	96.68 ba	117.72 NS[2]
NF1 x BPM	102.1 ba	125.00 NS
NF1 xSM	58.41 c	112.97 NS
NF2 x WM	79.79 bc	137.42 NS
NF2 x BPM	114.66 a	136.60 NS
NF2 x SM	82.34 bc	109.08 NS
NF3 xWM	77.82 bc	119.13 NS
NF3 x BPM	91.19 ba	127.16 NS
NF3 x SM	97.35 ba	133.81 NS

[1] different letters with an average value of the yield point to the existence of significant differences according to Duncan test at level $p< 0,05$; [2] NS- not significant differences

In BPM treatments maximal values of N min were generally determined and the lowest ones in WM (Fig. 3). The main reason for it is known properties of the BPM in terms of protection against loss of N by rainfall (Romić et al., 2003) and faster soil warming under BPM in relation to the accumulation of N min (Zhang et al., 2012). During vegetation amount of N min in the soil was decreased as the differences between mulched and non-mulched treatments were reduced. It can be explained by the fact that after the closure of tomato canopy, the differences in the soil temperature between mulched and non-mulched treatments are reduced (Grbac et al., 2010) and mulch has no influence on the growth and fruiting of tomatoes (Teasdale and Abdul Baki, 1995).

In both years NF had no significant effect on yield of tomatoes, while under the BPM the yield was significantly increased only in 2007 (Table 6). The highest yields were achieved by NF2 and BPM treatments, and the lowest by NF1 and SM treatments. The total yield of tomatoes in 2009 was higher compared to 2007, as the average air temperature at the time of tomato harvest was higher by 3.6°C, which probably facilitated the quality of fruit ripening. Moreover, a 114.9 mm of precipitation in May 2007 favored the occurrence of downy mildew, and reduction of the yield. By increasing of N fertilization from 120 to 180 kg N ha^{-1}, a total yield of tomatoes was reduced to 3.54 t ha^{-1} in 2007 and 1.00 t ha^{-1} in 2009. The yield reductions caused by increased N fertilization was also determined by Elia and Conversa (2012). In both years effect of NF on total yield of tomatoes was not significant. In 2007 was obtained significantly higher yield with BPM (102.65 t ha^{-1}) compared to SM (79.37 t ha^{-1}) and WM (84.77 t ha^{-1}), among which was no statistically significant difference (p <0.05). This is the result of positive impact of the BPM on early yield formation and faster ripening of tomatoes in relation to other mulch treatments. The lower yield of tomatoes under straw is the result of the occurrence of lower temperature under this type of mulch and tomato comes later into the generative stage. The lowest total yield in 2007 was obtained in the NF1 with SM (58.41 t ha^{-1}) and the highest in the NF2 with BPM (114.66 t ha^{-1}). From ecological point of view, in the conditions of Valutra, N fertilization with 60 kg N ha^{-1} would be sufficient for tomato production. These amounts are lower than the 90 kg N ha^{-1} recommended by Samaila et al. (2011). In Italy, the optimum amount of N is 200 kg N ha^{-1} (Tei et al., 1997).

Conclusions

Increased doses of N fertilizer in both years had a significant impact on the amount of N min in the soil, although it did not result in significantly higher total yield of tomatoes. The mulch partly influenced (2009) the amount of N min in the soil and the total yield of tomatoes. The highest yields were determined in combination with BPM and fertilization with 120 kg N ha^{-1}. The application of N fertilizer with 60 kg N ha^{-1} with BPM would be ecologically acceptable, but from the economic point of view the optimal fertilization would be 120 kg N ha^{-1} with use of BPM. After harvesting the tomatoes, in soil remained even 80 kg N ha^{-1}. This karst area in Istria is an environmentally vulnerable and it is necessary to adjust the recommended amount of N added by fertigation according to the needs of tomato and environmental conditions.

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